COSMICAL THERMODYNAMICS.

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(*Read before the American Philosophical Society, April 17th,* 1874.)

A committee* has been appointed to invite the participation of Students in the discussion of a paper which will be presented at the coming autumn meeting of the Association of German Naturalists and Physicians. The paper is entitled "*Lösung des Problems über Sitz und Wesen der Anziehung,*" its object being the identification of gravitating force with thermo-dynamics, by means of the thermal equivalent and Carnot's law of thermo-dynamic energy.

In compliance with the invitation, and as a contribution to the general theory of unitary force, I submit the following Theses, together with references to portions of my communications to the American Philosophical Society during the past eleven years, in which some of them are practically exemplified and verified.

1. If Force is unitary in its origin, it should be omnipresent in its manifestations.

2. In a supposed universal, material, elastic and therefore slightly compressible, luminiferous æther, we may reasonably look for such omnipresent, primitive manifestations.

3. In a universally undulating æther, any gross inertia of points or particles, must establish special systems of both centripetal and centrifugal undulations.

4. The gross, inert particles, in an æthereal ocean, would be impelled towards each other with velocities varying directly as the sum of their inertias and inversely as the square of their distance.

5. As soon as a revolution is established around the common centre of gravity of three nearly equal particles, under the influence of æthereal undulations, there should be a tendency to discoid aggregation with a central spheroidal nucleus.

6. On account of æthereal elasticity, there should also be a subordinate tendency to aggregation along lines of logarithmic parabolas or spirals.

7. In an infinitely diffused nebulous mass, all work would be internal.

8. In a finite, condensing, nebulous mass, there would be external work, especially manifested in attraction, revolution, and rotation.

9. As condensation progresses, v' (the velocity of revolution of a free equatorial particle) $\propto \sqrt{\frac{1}{r}}$; v'' (the velocity of rotation of a constrained equatorial particle) $\propto \frac{1}{r} \propto (v')^2$; g (the velocity of centripetal impulsion) $\propto \left(\frac{1}{r}\right)^2 \propto (v'')^2 \propto (v')^4$.

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10. The foregoing postulates are all equally true, whether the centripetal impulse originate in a thrust, or in a pull.

11. We have no direct evidence of any primitive pull, but we have evidences of radiating thrusts of light and heat from stellar centres.

12. In all known cosmical motions, the centrifugal and centripetal forces act under such laws of equilibrium, that the apparent pull of gravity may be explained by the difference between external and intermediate radiating thrusts.

13. We know of oscillations in the æthereal sea, propagated with v^{λ} (the velocity of light). The communication of an exceedingly minute portion of that velocity to inert particles, would be sufficient to produce all the phenomena of gravitation.

14. The greatest manifestation of gravitating force in our system (g at Sun's surface) $= 875.618$ ft. $= 875.618 \times 584{,}400 = 511{,}711{,}159$ mean light-waves per second. There being $592\ (10)^{12}$ mean light-waves per second, that force could be produced by $\frac{511{,}711{,}159}{592\ (10)^{24}} = \frac{1}{1157\ (10)^{15}}$ of the mean velocity of each light-wave.

15. If gravity were propagated with infinite velocity, and any inert mass were concentrated in a point, a body falling to that point would obtain an infinite velocity.

16. If gravity is the resultant of oscillations of finite velocity, and if solar rotation, planetary revolution, and solar motion in space, are all resultants of gravitating action, their velocities should all be limited by v^{x} (the velocity of the primary efficient oscillation).

17. In a homogeneous circular disc, of infinitesimal thickness, $g \propto$ distance from centre.

18. If such a disc were revolving in a circular orbit, under the combined influence of tangential and centripetal thrusts, in a slightly compressible æthereal ocean, it should rotate as well as revolve, the limit of possible rotating velocity being v^{x}.

19. If the supposed disc should acquire such a velocity that at the periphery $v' = v'' = \sqrt{gr}$, the same equations would be true for every particle in the disc.

20. In a sphere or spheroid, the superficial centripetal thrusts should produce an increase of density at and towards the centre.

21. The ratio of the rotating action of an æthereal stream on the equatorial plane of a nebulous sphere, to the propelling force of the same stream acting on the spherical surface, is $\pi r^2 : 4\pi r^2$, or 1:4.

22. In a rotating and revolving star, planet, or satellite, each equatorial particle oscillates in waves which have a height equivalent to twice the distance of the particle from the centre of gravity of the rotating body.

23. If $t'' =$ time of rotation, the integral of the impulses communicated during each rise or fall of the rotation-wave, is $\frac{gt''}{2}$.

24. If the rotating body were to expand or contract uniformly, $v'' \propto \frac{1}{r}$, and $t'' \propto r^2 \propto \frac{1}{g}$; $\frac{gt''}{2}$ is $\therefore$ a constant quantity for each particle.

25. At the trough of the rotation-wave, the accumulated retrograde velocity is exactly equal to the originating velocity of tangential orbital impulsion. In other words, $\frac{gt''}{2} = v^x$.

26. The velocity of rotation would become equal to the velocity of revolution, when the sphere had contracted so that $\frac{gt''}{2\pi} = \frac{gt'}{2\pi} = \frac{v^x}{\pi}$. The limiting velocity of inertial aggregation is, therefore, such as would carry a body through the equatorial diameter of a spheroid, while v^x would describe its equatorial circumference.

27. The elasticity of the æther should give rise to harmonic vibrations, and especially to vibrations which involve multiples of $\sqrt{2}$,* 3,† $\sqrt{.4}$,‖ and π§.

28. In consequence of the harmonic vibrations, there should be a tendency to the establishment of points of inertia, and the consequent aggregation of planets and satellites, at harmonic nodes. Such a tendency is illustrated by the Chladni plates, and the 14th Thesis shows that the supposed cause of aggregation is more than adequate for the production of the supposed effects.

29. The blending of different harmonic vibrations should produce secondary vibrations of a lower order, giving rise to varying orbital eccentricities.

30. The influence of harmonic vibrations should be traceable, not only in planetary positions, but also in their masses, momenta, and moments of inertia.

31. The æthereal action upon inert masses or particles, should be followed by a reaction of the particles upon the æther. Subordinate rotating impulsions should thus be established among the planets, and satellites, and particles.

32. The same harmonic laws which introduce order among the various bodies of the macrocosmic system, should also be operative in various forms of orderly arrangement, within each of those bodies.

*The velocity of fall from infinite distance $= \sqrt{2gr}$.

†Centre of linear oscillation $= \frac{2}{3} l$.

‖Centre of spherical oscillation $= \sqrt{2}\ r$.

§See Thesis 26.

33. The superiority of the wave-theory over the equilibrium theory of tides, demonstrates the importance of considering the cumulative effect of successive impulses, both in molar and in molecular investigations.

34. The height of the atmosphere is sufficient to give the total wave tide a position identical with the equilibrium-tide, with the crest vertically under the disturbing body.

35. The stratification of the atmosphere, indicated by the various currents, should often produce tides in the lower couches of the air identical in position with the ocean tides, with the trough vertically under the disturbing body.

36. The resultant of the tangential and radial orbital impulses upon the elastic atmosphere, combined with the resistance of the earth's surface, should produce daily barometric fluctuations, of such general form and magnitude as have been observed.

37. All tidal influences upon the atmosphere, whether thermal or gravitating in their immediate dependence, should be modified in accordance with Ferrel's laws.

38. There should be cumulative annual as well as daily barometric tides, and in consequence of the tendency to maintain "equality of areas," the two should be so connected as to furnish data for approximate estimates of the Sun's distance.

39. Local temperature should be a measure of the work accomplished by the various local æthereal impulses. The average temperature of different latitudes should, therefore, be determinable by *a priori* mathematical calculation.

40. The barometric tides, if they are dependent upon elastic æthereal waves, should furnish some indications of the elasticity and resistance of the æther.

41. If the disturbances of the moon and planets upon the atmosphere, are produced through the intervention of undulations, and therefore cumulative, evidences of such disturbances should be found in the cycles of meteorological phenomena. The disturbances should be of a greater magnitude than any that are attributable to mere differential-tidal attraction.

42. The velocity and length of sound waves should bear some definite harmonic relation to the mean velocity of the atmosphere, as well as to the velocity and length of the waves in the primary efficient undulation.

43. The daily and annual variations of magnetic needles, should be similar to those which would be produced by mechanical vibrations simulating the thermal currents in the atmosphere.

44. Harmonic analogies should afford probable bases for astronomical, physical, and chemical anticipations.

45. Harmonic relations should be traceable, between gaseous oscillations relatively to the Sun and any given planet, which are dependent upon the relative masses of the disturbing bodies.

46. If gaseous particles are uniformly distributed along a given line

in consequence of an explosion, a secondary centre of linear oscillation should be established between the primary centre and the centre of gravity, $[\frac{2}{3} - \frac{2}{3} \text{ of } (\frac{2}{3} - \frac{1}{2}) = \frac{5}{9}]$.

47. Planets and satellites, oscillating under the combined action of centrifugal and centripetal forces, and subject to disturbances from mutual interaction, should tend to arrangements analogous to those of the particles in an exploded gas.

48. The force of superficial gravity, at the Sun and at the principal planets, should be in simple harmonic relations to other elements of planetary motion.

49. The laws of mechanical arrangement, in the particles of a homogeneous elastic æther, should give rise to polar forces.

50. The velocity of primary oscillation (Theses 16, 25, &c.,) *which satisfies the foregoing theses, by explaining all velocities which are the resultants of gravitating force, is the velocity of light.*

These Theses seem to me to be all rigorously and mathematically connected with the hypothesis of a universal elastic æther. In my accounts of the successive tentative steps, inductive, deductive, and anticipative, by which I have been brought to their recognition, there has necessarily been much that was crude, and some things that were perhaps merely visionary, but the steps have all led towards the same goal. While endeavoring to learn caution from my mistakes, I have never ceased for a moment to believe that the many harmonies and coincidences which I have pointed out, were indicative of important but unknown laws.

The identification of v^x and v^λ, (Thesis 50), is perhaps the most important conclusion of the whole, and its importance may render somewhat fuller details desirable. The common explanation of planetary motions, assumes a primitive tangential impulse and a constant gravitating pull, the resultant of the two forces determining the path at every instant. But it should be remembered that the efficient tangential impulse is by no means the one which was originally communicated; that it, as well as the pull of gravity, is continually shifting its direction, and continually renewed; and that all the known cosmical motions can be as readily accounted for by the impulse of waves upon particles differing in their relative amounts of inertia, as in any other way.

In any case of free orbital revolution around a centre of gravity, every infinitesimal pull of gravitation is assumed to be efficient, in some way or other. If the orbit is circular, the orbital velocity $(\sqrt{gr})$ is renewed, as often as a portion of the orbit, equivalent to radius, has been described. This fact is, of itself, suggestive of equal oscillations, either alternately or simultaneously centripetal and tangential, and it may well justify us in looking for some equally simple relationship to an invariable velocity of primitive and continual impulsion.

The only presumably invariable velocity that we know, being that of light, and the only mode of viewing gravitating action, under an invariable relation to a uniform velocity, being the one which I have pointed out in Theses 23 and 24, there seems to be an *a priori* probability that v^λ may be represented by some simple function of the constant velocity gt'', and that gravitating motion, as well as light motion, may be undulatory. Since gravitating fall acts, in orbital motion, until the sum of successive gravitating impulses has communicated a tangential velocity equal to $\sqrt{gr}$, thus renewing the orbital velocity, it seems natural enough to suppose that the same fall may also act, in rotary motion, until the sum of successive impulses has communicated a centripetal velocity $= v^x = v^\lambda$, thus renewing the velocity of primary impulsion. If the gravitating thrusts or pulls are supposed to be all efficient, it is not only right, but it is even our duty, as earnest truth-seekers, to try to trace their efficiency as far as possible.

In the oscillation described in Thesis 22, each equatorial particle is alternately approaching to, and receding from, the orbital centre of gravity, during intervals of a half rotation. The integral of gravitating impulses, at the centre of our system, during each wave rise or fall, is, perhaps, as closely identified with the velocity of light, as is the integral of gravitating impulses, during the orbital description of radius, with the orbital velocity. For, from the equation $\frac{gt''}{2} = v^x = v^\lambda$, we deduce, for the time of solar rotation, $t'' = \frac{1}{2 \times 497.827} \times \left(\frac{1}{214.86\pi}\right)^2$. This value differs, *by less than* $\frac{5}{6}$ *of one per cent.*, from the estimate of Bianchi, Laugier, and Herschel, and by less than $3\frac{1}{3}$ per cent. from that of Spörer, which is the lowest estimate hitherto published. From the constant solar equation, $\frac{gt''}{2} = v^\lambda$, we readily obtain, by introducing the variable r, the general equation for planetary velocity, $\sqrt{gr} = \sqrt{\frac{2rv^\lambda}{t''}}$

The following references are to the published volumes of the Proceedings of the American Philosophical Society, except when otherwise specified. The Arabic numerals, prefixed to each set of references, denote the Thesis which they verify or exemplify.

2. ix. 371, April 15, 1864; ix. 427, 432, Oct. 21, 1864; x. 98, April 21, 1865; xii. 392, Feb. 16, 1872; xii. 411, July 19, 1872; Trans. Amer. Philos. Soc., xiii. Art. VI.

3. xi. 103, April 2, 1869; xiii. 140, 142, Feb. 7, 1873.

4. xiii. 245, May 16, 1873.

6. xii. 518-22, Sept. 20, 1872; xiii. 193, 244, April 4, May 16, 1873.

9. xiii. 146, March 7, 1873; xiii. 243, 245, May 16, 1873.

12. xiii. 193, April 4, 1873.

13–26. ix. 408, July 15, 1864 ; xi. 103, April 2, 1869 ; xiii. 148, March 7, 1873 ; xiii. 245, May 16, 1873 ; xiv. 111–3, Feb. 5, 1874.

27–32. x. 261-9, Sept. 21, 1866 ; x. 358, Nov. 15, 1867 ; xii. 392–400, Feb. 16, April 5, 1872 ; xii. 403-17, May 16, July 19, 1872 ; xiii. 140-54, Feb. 7, 16, March 7, 21, 1873 ; xiii. 193-8, April 4, 1873 ; xiii. 237-48, May 2, 16, 1873 ; xiii. 470-7, Oct. 3, 1873 ; xiv. 111–3, Feb. 5, 1874.

33. ix. 283-8, Dec. 18, 1863 ; ix. 292, Jan. 1, 1864 ; ix. 346-9, March 4, 1864 ; ix. 367-71, April 15, 1864 ; xii. 178-90, Aug. 18, 1871 ; *et passim.*

34–5. x. 523-33, Oct. 2, 1868 ; xii. 180, Aug. 18, 1871 ; xii. 525, July 19, 1872.

36. ix. 284, Dec. 18, 1863.

37. Mathematical Monthly, i. 140, sqq. ; January 1859, and continued in subsequent Numbers, some of the results having been published about two years before, in the Nashville Journal of Medicine and Surgery.

38. ix. 287, Dec. 18, 1863.

39. ix. 346-8, March 4, 1864 ; ix. 395 9, June 17, 1864 ; x. 261-9, Sept. 21, 1866.

40. ix. 292, Jan. 1, 1864 ; ix. 408, July 15, 1864.

41. x. 261-9, Sept. 21, 1866 ; x. 439, June 19, 1868 ; x. 530-3, Oct. 2, 1868 ; xi. 113, May 7, 1869 ; xi. 203, Oct. 1, 1869 ; xii. 38-40, March 3, 1871 ; xii. 65-70, March 17, April 7, 1871 ; xii, 121-3, May 5, June 16, 1871 ; xii. 178-90, Aug. 18, 1871 ; xii. 400, April 5, 1872 ; xii. 523-9, Oct. 18, 1872 ; xii. 556-9, Nov. 1, 1872.

42. xi. 109, April 2, 1869 ; xiii. 150, March 21, 1873.

43. ix. 359, 367-71, April 1, 15, 1864 ; ix. 427-40, Oct. 21, 1864 ; x. 98, 111, sqq., April 21, May 19, 1865 ; x. 151-66, Oct. 6, 1865 ; x. 358, Nov. 15, 1867 ; xiii. 153, March 21, 1873 ; Trans. Amer. Philos. Soc., xiii. Art. VI.

44. ix. 284, Dec. 18, 1863 ; xiii. 140, sqq., Feb. 7, March 21, 1873 ; xiii. 237, 252, May 2, 16, 1873 ; xiii. 470, Oct. 3, 1873.

45. xii. 392, sqq., Feb. 16, 1872 ; xiii. 142, Feb. 7, 1873.

46–8. xi. 103-7, April 2, 1869 ; xii. 392, sqq., Feb. 16, March 1, May 16, July 19, 1872 ; xiii. 140, sqq., Feb. 7, March 7, 1873.

49. ix. 359, 367-9, April 1, 15, 1864 ; xii. 407-8, May 16, 1872.

50. ix. 408, July 15, 1864 ; ix. 427, 432, Oct. 21, 1864 ; x. 261-9 ; Sept. 21, 1866 ; xi. 103, sqq., April 2, 1869 ; xiii. 149, March 7, 1873 ; xiii, 245, May 16, 1873 ; xiv. 111–3, Feb. 5, 1874 ; *et passim.*